

Environmental and Energy Benefits of
Microprocessor Control of Oven Airflows for a
Coil Coating Operation: A Case Study

Chemical Coaters Association, Wheaton, IL

Prepared for

Industrial Environmental Research Lab.
Cincinnati, OH

Nov 84

EPA-600/2-84-179
November 1984

ENVIRONMENTAL AND ENERGY BENEFITS
OF MICROPROCESSOR CONTROL
OF OVEN AIRFLOWS FOR
A COIL COATING OPERATION

A CASE STUDY

By

Chemical Coaters Association
CENTEC Corporation
Prior Coated Metals Inc.

Cooperative Agreement No.
CR 8070833010

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UNITED STATES DEPARTMENT OF ENERGY
OFFICE OF INDUSTRIAL PROGRAMS
WASHINGTON, DC 20585

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-84-179		2.		3. RESIDENT'S ACCESSION NO. PB85 121135	
4. TITLE AND SUBTITLE Environmental and Energy Benefits of Microprocessor Control of Oven Airflows from a Coil Coating Operation: A Case Study				5. REPORT DATE November 1984	
				6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) Charles H. Darvin Centec Inc. Reston, VA 22090				8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Chemical Coaters Association P.O. Box 241 Wheaton, IL 60187				10. PROGRAM ELEMENT NO. 9HA1A	
				11. CONTRACT/GRANT NO. CR 8070833010	
12. SPONSORING AGENCY NAME AND ADDRESS Industrial Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268				13. TYPE OF REPORT AND PERIOD COVERED Final Task	
				14. SPONSORING AGENCY CODE EPA/600/12	
15. SUPPLEMENTARY NOTES					
16. ABSTRACT In most industrial operations the percentage of the lower explosive limit (LEL) of VOC emissions typically remain at below 5 to 10 percent LEL at most metal coating operations. Although monitors are available to determine solvent concentration in the oven, the oven requires manual corrective action to the process when potentially explosive oven atmosphere are generated. In 1982 a project was completed that developed and demonstrated the viability of using microprocessor technology to make VOC control of paint curing ovens less expensive than present operations. This would be accomplished by lowering oven ventilation air flow and safely increasing LEL concentration to a maximum 50 percent. However, the demonstration system was not operated at maximum LEL concentration, thus the versatility of the system to operate at high LEL concentration was not determined. This project evaluates the system at a commercial facility while operating at a concentration approaching 50 percent LEL. Included in the report is a description of the oven modification at the Prior Coated Metals Coil Coating facility in Allentown, Pennsylvania and the oven operating conditions before and after the modifications. Also included is the operating economics of the oven and VOC control system.					
17. KEY WORDS AND DOCUMENT ANALYSIS					
a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group	
Industrial Painting Air Pollution Energy Conservation Volatile Organic Compounds		Metal Finishing Metal Painting Computer Control Paint Bake Ovens Paint Curing			
18. DISTRIBUTION STATEMENT		19. SECURITY CLASS (This Report) Unclassified		21. NO. OF PAGES 42	
		20. SECURITY CLASS (This page) Unclassified		22. PRICE	

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on the environment and even on health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) and the Office of Industrial Programs, U.S. Department of Energy, Washington, D.C., assist in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report is an evaluation of the commercial application of micro-processor technology to enhance control of volatile organic compound emissions from a paint curing coal coating oven and simultaneously reduce the energy requirements and operating costs of the curing process. The program was cosponsored by the Chemical Coaters Association, the United States Department of Energy and the U.S. Environmental Protection Agency and has resulted in a fully demonstrated technology ready for immediate commercial application. Questions or comments regarding this report should be addressed to the Non-ferrous Metals and Minerals Branch of the Industrial Environmental Research Laboratory in Cincinnati, Ohio.

David G. Stephan
Director
Industrial Environmental Research Laboratory- Cincinnati

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ABBREVIATIONS

AIT	- Analyzer Indicating Transmitter
CCA	- Chemical Coaters Association
DCF	- Discounted Cash Flow
F	- Fan (blower)
FID	- Flame Ionization Detector
FCV	- Flow Control Valve
FQI	- Natural gas meter
ft/min	- feet per minute
gal/min	- gallons per minute
I/P	- Electrical to Pneumatic
kg/s	- kilograms per second
kW	- kilowatts
LEL	- Lower Explosive Limit
lb/h	- pounds per hour
lb/in ² g	- psig
m/s	- meters per second
m ³ /s	- meters cubed per second
MW	- megawatts
NFPA	- National Fire Protection Association
Pa	- Pascal
P&I	- Process and Instrumentation
PPM	- Parts Per Million
PT	- Pressure Transmitter
R	- Recirculation blower and burner
stdft ³ /min	- Standard Cubic Feet Per Minute
TC	- Temperature indicator
TIC	- Temperature Indicator Controller
TII	- Total Installed Investment
TT	- Temperature Transmitter
VOC	- Volatile Organic Compounds

ACKNOWLEDGMENTS

We would like to acknowledge the contributions of the Chemical Coaters Association (CCA) and its technical committee members, Matt Heuertz, Merle Kvaal, Ron Ludden, John Lipscomb, Philip Vadeboncoeur, Eugene Ingram, and Floyd Young for their work in providing overall technical and management support to this project.

Also, CCA acknowledges the engineering work of Messrs. Terence Karda, Kenneth Holladay, Charles Rowan and Milton Ryals of CENTEC Corporation and Greg Gemgnani of Prior Coated Metals, Inc.

We wish also to acknowledge Mr. Nicholas J. Bouras, President of Prior Coated Metals, Inc. for his approval to conduct the study and for use of Prior's facility in Allentown, Pennsylvania.

SECTION 1

INTRODUCTION

During the manufacturing process, painted consumer products pass through a curing step. This occurs immediately after the coating has been applied. The curing step is accomplished in an oven (dryer) by passing large volumes of hot air around the product to effect the cure of the paint on the product. The energy sources for these ovens are usually steam, produced from burning natural gas or fuel oil. Natural gas is the most widely used.

For coatings containing organic solvents, curing ovens require large volumes of ventilation air to maintain the solvent concentration below its lower explosive limit (LEL). The maximum allowable solvent concentration inside the oven, as set by the National Fire Protection Association (NFPA), is to be maintained below 25 percent of the LEL unless a vapor concentration indicator and controls are installed to assure safe operation. Because the coating rate and solvent composition vary, the ventilation air flow rate is normally much higher than would be required to meet NFPA Codes and curing needs. Excessively high ventilation air flow rates mean higher energy demand for curing and excessive energy and investment costs for meeting environmental compliance associated with volatile organic compound (VOC) and odor emissions.

The U.S. Environmental Protection Agency, the Department of Energy, and the Chemical Coaters Association recently completed a program, "Environmental and Energy Benefits of Microprocessor Control of Oven Airflows From Metal Painting Operations," to demonstrate through the use of microprocessor control that the ventilation air flow rate could be significantly reduced, thereby reducing the energy costs for curing and incineration. The sponsoring agencies stipulated that the demonstration control system be evaluated in the miscellaneous metal parts sector of the coating industry.

The site selected for the demonstration of the prototype control system was Mack Trucks, Inc. in Allentown, Pennsylvania. The Mack Trucks continuous conveyor oven was located in Building 514 Assembly Plant. The system was successfully started up during October 1981. Table 1 is a summary of the oven conditions immediately before and after the system was placed in automatic control.

Table 1. MACK TRUCKS CURING LINE CONDITIONS

Manual and Automatic Operation

<u>OPERATING CONDITIONS</u>	<u>Oct 5-16 Manual Operation</u>	<u>Oct 26-Nov 6 Automatic Operation</u>
<u>Dip Oven</u>		
Air Flow, std m ³ /s (stdft ³ /min)	1.60 (3400)	0.23 (490)
Exhaust Temp, °C (°F)	122 (252)	139 (282)
Avg. Exhaust Solvent Conc, % LEL	<1.0	3.0
Fuel Consumption, kW (million Btu/h)	510 (1.74)	226 (0.77)
<u>Prime Oven</u>		
Air Flow, std m ³ /s (stdft ³ /min)	0.94 (2000)	0.94 (2000)
Exhaust Tem, °C (°F)	121 (250)	121 (250)
Avg. Exhaust Solvent Conc, % LEL	<1.0	<1.0
<u>Color Oven</u>		
Air Flow, std m ³ /s (stdft ³ /min)	0.94 (2000)	0.94 (2000)
Exhaust Temp, °C (°F)	121 (250)	121 (250)
Avg. Exhaust Solvent Conc, % LEL	<1.0	<1.0
<u>Auxiliary Fume Tunnel</u>		
Air Flow, std m ³ /s (stdft ³ /min)	0.87 (1840)	0.87 (1840)
Exhaust Tem, °C (°F)	70	70
Avg. Exhaust Solvent Conc, % LEL	1.0	3.0
<u>Catalytic Incinerator</u>		
Total Air Flow, std m ³ /s (stdft ³ /min)	4.36 (9240)	2.99 (6330)
Inlet Temp, °C (°F)	125 (257)	138 (281)
Exhaust Temp, °C (°F)	419 (787)	442 (828)
Destruction Efficiency, %	84.5	93.6
Fuel Consumption, kW (million Btu/h)	1382 (4.72)	1218 (4.16)
Fuel Consumption in Dip Oven & Incinerator, kW (million Btu/h)	1892 (6.46)	1444 (4.93)
Fuel Reduction in Dip Oven & Incinerator, kW (million Btu/h)		448 (1.53)
Fuel Cost Saving in Dip Oven & Incinerator, \$/yr ¹		22,800

¹ Assumes \$6.98 per million Btu fuel oil cost, 9 hours per day, 237 days per year.

Although all safety and control functions were tested and demonstrated at Mack Trucks, the system was not operated at solvent concentrations above 25 percent of the LEL. The limiting operating parameter at the Mack Truck demonstration was found to be the oven pressure rather than solvent concentration. Thus, the microcomputer controlled the minimum ventilation air flow rate to maintain a negative pressure for the curing oven in order to prevent fumes from discharging to the working area. The pressure control points, combined with a reduction in the production level due to a depressed truck market, produced a low solvent concentration inside the oven with a low total ventilation air flow rate of 0.23 standard m³/s (490 stdft³/min).

After successful completion of the Mack Trucks demonstration, an evaluation of this control concept for other sectors of the coating industry was requested by the sponsoring agencies. In particular, curing ovens where high solvent evaporation rates are normally encountered were considered to be good applications for installation of these control systems. An evaluation of the system under these conditions would prove the capability of the technology under high solvent concentrations.

This report presents the results from the installation of a microprocessor control system for a coil coating oven. The extension of the control concepts initially proven at Mack Trucks has been successfully implemented by Prior Coated Metals, Incorporated's facility in Allentown, Pennsylvania. Prior Coated Metals' curing oven is operated over a range of solvent evaporation rates and compositions which reach the control set point normally set at 30 percent of the LEL or the pressure control set points. This report therefore is intended to provide the coating industry with additional information to assess the applicability of microprocessor control systems for their site-specific requirements.

SECTION 2

CONCLUSIONS

The evaluation of the operation of a microcomputer-based control system at Prior Coated Metals and results from Mack Trucks' installation provides the following conclusions:

- Control of Solvent Concentrations

Solvent levels in continuous curing ovens can be continuously controlled at levels above 25 percent of the LEL. The location of the highest solvent concentration is dependent upon the type of coating used and curing oven temperature. At Mack Trucks, the location of the highest solvent concentration remained in the same location since the curing conditions, coating rate and formulations were not changed. At Prior Coated Metals the location changed and was dependent upon the types of products and coatings being cured.

- Sampling Points for Monitoring and Control

Multiple sampling points for measuring solvent concentrations inside continuous multi-zone curing ovens are required for ventilation air flow rate control since the location of maximum solvent release varies with coating. At Mack Trucks, the exhaust concentration was approximately 50 percent lower than the highest solvent concentration inside the curing oven; the same result occurred at Prior Coated Metals. The control of the ventilation air flow rate should not be based on the solvent concentration in the exhaust ducts. The local concentrations inside the oven can greatly exceed the concentration in the exhaust duct.

- Microprocessor Applicability

The microprocessor control technology was proven to be applicable for conveyor ovens (Mack Trucks) and coil coating ovens (Prior Coated Metals).

- Product Quality

Product quality was not affected by a reduction in ventilation air flow rate at Mack Trucks or Prior Coated Metals.

- Ventilation Air Flow Control

Ventilation air flow rate reduction for curing ovens are achievable under automatic control. At Mack Trucks, the ventilation air flow rate was decreased from 16 to 0.23 standard m^3/s (3400 to 490 stdft³/min). At Prior Coated Metals, the air flow rate was reduced from 7.27 standard m^3/s (15,400 stdft³/min) to approximately 1.89 standard m^3/s (4000 stdft³/min) under pressure control and automatically increased to the required rate for controlling the solvent concentration (percent of the LEL) inside the curing oven.

- Investment Costs for VOC Emission Control

Prior's total installed investment for the thermal incinerator was \$127,400. Prior's projected installed costs for a thermal incinerator with 80 percent primary heat recovery without the microcomputer controller was above \$550,000. By controlling and reducing the ventilation air flow rates, the total installed investment can be reduced for achieving VOC emission control since a smaller control system is needed to control the reduced air flow.

- Monitoring Destruction Efficiency of Incinerator

The destruction efficiency of a thermal incinerator (Prior Coated Metals) and catalytic incinerator (Mack Trucks) can be continuously monitored using microcomputer and sampling the solvent concentrations at the inlet and exhaust of an incinerator.

SECTION 3

NEW PROCESS/PLANT MODE

DESCRIPTION OF FACILITY BEFORE RETROFIT

Prior Coated Metals, Inc. operates a toll coil coating facility in Allentown, Pennsylvania. The coated metal is used for such end products as 35mm cartridges for camera film, refrigerator liners, roof decking, lighting reflectors and housing. Generally Prior's coating formulations are polyester, epoxy, solution vinyl, and plastisol based.

The layout of the coating area, curing oven, incinerator and quench systems prior to retrofit is shown in Figure 1. The coating is applied to the strip using roller applicators. The coil continuously passes through a three-zone, natural gas, direct-fired curing oven into the quench zone where water is sprayed on the coil to cool it.

The curing oven was initially installed in 1962 at the time the facility was built. The incinerator was installed in 1969.

Because of the wide range of coatings applied to the product, the solvent evaporation rate, solvent compositions, and curing temperatures vary considerably from one product to another. Oven temperatures are in the range of 232 to 427°C (450°F to 800°F).

The solvent evaporation rate in the curing oven is dependent upon the volume of solvent in the coating, amount of coating applied to the coil, line speed, and strip (coil) width. Line speed varies between 0.51 m/s (100 ft/min) to a maximum of 0.91 m/s (180 ft/min), depending upon the width and gauge thickness and curing properties of the coating. The solvent evaporation rates are in the range of 0.01 kg/s (0.00001 m³/s) [45 lb/h (0.1 gal/min)] to 0.06 kg/s (0.0001 m³/s) [450 lb/h (1 gal/min)] with 0.02 kg/s (0.00003 m³/s) [180 lb/h (0.4 gal/min)] being the average rate. Approximately 5 percent of the solvent evaporates as the coating is applied in the coater room. Table 2 shows a set of typical conditions for coater room, curing oven, incinerator, and quench zone before retrofit.

The coater room was designed to exhaust air from two locations. One blower provided combustion air to the three burners, one in each zone of the curing oven, at a total air flow rate of approximately 0.57 m³/s (1200 stdft³/min).

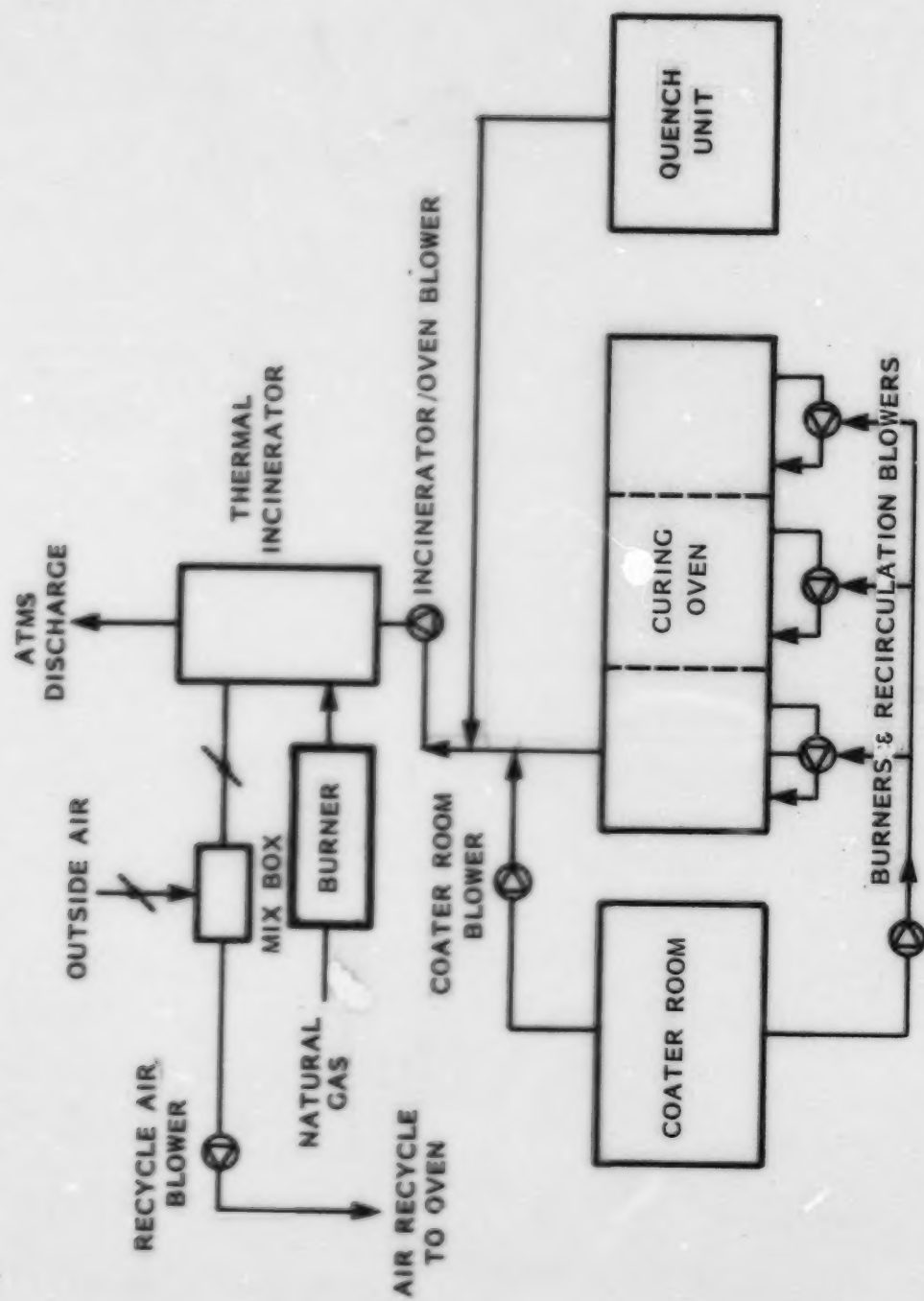


Figure 1. Prior Coated Metals facilities before retrofit.

Table 2. TYPICAL OPERATING CONDITIONS
AND FUEL DEMAND BEFORE RETROFIT¹

CURING OVEN CONDITIONS	1	2
Line Speed, m/s (ft/min)	0.91 (180)	0.91 (180)
Solvent Rate, m ³ /s (gal/min)	0.0003 (0.4)	0.0003 (0.4)
Air Flow Rates, std m ³ /s (stdft ³ /min)		
- Direct recycle from mix box	2.22 (4700)	2.22 (4700)
- Oven ventilation air	5.76 (12,200)	7.27 (15,400)
- Quench air exhaust to incinerator	0.44 (940)	0.44 (940)
- Coater room air exhaust to incinerator	0.33 (690)	0.33 (690)
- Total incinerated air	6.51 (13,800)	8.03 (17,000)
Average exhaust concentration % of LEL	6	5
Oven exhaust temp, °C (°F)	382 (720)	249 (480)
Direct recycle temp, °C (°F)	182 (360)	182 (360)
<u>Fuel Demand, MW (million Btu/h)</u>		
Total Curing Oven	3.31 (11.3)	2.43 (8.3)
Total Incineration	1.76 (6.0)	3.16 (10.8)
Metal Heating	0.32 (1.1)	0.23 (0.8)
Radiation Losses	0.59 (2.0)	0.59 (2.0)
Total Energy Demand	5.98 (20.4)	6.41 (21.9)
Annual Average Hourly Fuel Demand		5.15 (17.6)

¹Data reported by Prior Coated Metals; calculated values for air heating, strip heating, and radiation losses. Incinerator operating temperature was set at 649°C (1200°F), equilibrium exhaust temperature of 538°C (1000°F) used for calculating incinerator fuel demand.

The curing oven had one external exhaust duct. Three internal ducts were joined together to form the single exhaust duct. One internal duct was located in each zone. The main blower operated at a total air flow rate of approximately 13.69 actual m^3/s (29,000 stdft³/min). For an average curing oven exhaust temperature of 249°C and 388°C (480°F and 730°F), the curing oven total exhaust air flow rate was 7.27 and 5.76 standard m^3/s (15,400 stdft³/min and 12,200 stdft³/min), respectively. The total air rate being incinerated was in the range of 6.51 to 8.03 standard m^3/s (13,800 to 17,000 stdft³/min) which included coater room and quench air.

The incinerator was originally purchased as a catalytic incinerator in 1962. Because of catalyst poisoning and plug-gage, the catalyst was removed after several years of operation. The incinerator was then operated as a thermal incinerator with a control set point of 649°C (1200°F). Because of the original design as a catalytic incinerator, the maximum design exhaust temperature was approximately 649°C (1200°F). At this set point, the equilibrium temperature (final exhaust temperature) for which destruction of the VOC emissions occurred was in the range of 538 to 593°C (1000 to 1100°F).

The incinerator was not equipped with any primary heat recovery and used ambient air as the source of combustion air for the burner. Secondary heat recovery, however, was used at Prior Coated Metals. The system, as shown in Figure 1, operated by recycle of a portion of the incinerator exhaust air to a mix box where outside ambient air was introduced to maintain the recycle air temperature in the range of 177 to 204°C (350 to 400°F). With the mix box blower, this air was directly recycled to each zone of the curing oven at a flow rate of approximately 2.22 standard m^3/s (4700 stdft³/min). The energy savings for the direct recycle was approximately 469 kW (1.6 million Btu/h).

The energy demands of Prior's plant before retrofit are also shown in Table 2 for two representative coatings. The curing oven total air heating demand was dependent on the curing temperature. The incinerator fuel demand was dependent upon the inlet temperature, total flow rate of the air entering the incinerator, solvent rate, and incinerator operating temperature. Prior's documented hourly fuel demand averaged over a year for air heating, radiation and strip heating, including the incinerator and curing oven, was 5154.6 kW (17.6 million Btu/h).

OBJECTIVES FOR RETROFIT

Prior Coated Metals initiated a project to upgrade and modernize the coating and curing operations. Specifically, four major objectives needed to be satisfied.

Emission Control - The old incinerator could not obtain a satisfactory destruction efficiency to achieve odor control because it could not be operated at temperatures above 649°C (1200°F). Prior's objective, therefore, was to modify the facility to eliminate sources of VOC emissions and odors being exhausted to the atmosphere. The possible sources of emissions requiring control were the coater room, curing oven, and quench system.

Energy Demand - The major energy consumers in Prior's facility were the curing oven and incinerator. Since natural gas costs had risen 50 percent from 1980 to 1982, the objective was to upgrade the curing oven and to optimize the energy demand for emission control that would be cost effective and, at the same time, meet their emission control objectives.

Coater Room Atmosphere - Fugitive solvent emissions in the coater room were to be reduced to levels acceptable to OSHA regulations and to coater room operators.

Safety/Curing Oven Controls - The only controls on the curing oven were temperature controllers for each zone. Air flow rates could not be increased or decreased with changes in line speed or solvent evaporation rates. In some instances, Prior ran some products at lower line speeds to assure that solvent concentrations at some locations inside the curing oven would not exceed those specified by the National Fire Protection Association 86-A Codes. The operating procedures were implemented because of the potential danger associated with fires or explosions if the curing oven was operated at a high coating rate where the solvent concentrations inside the oven would exceed 25 percent of the LEL. Also, Prior had no analyzers monitoring the solvent concentration inside the oven and it was their objective to keep the concentrations below 25 percent of the LEL according to the NFPA Codes.

PLANT MODIFICATIONS

The modifications implemented by Prior Coated Metals included a microcomputer controller for curing oven and incinerator to meet the above objectives, a thermal incinerator without primary or secondary heat recovery, curing oven mechanical modification, and new hoods for the coater room. The major equipment list is shown in Table 3.

Table 3. MAJOR EQUIPMENT LIST
PRIOR COATED METALS

<u>Item/Number</u>	<u>Supplier</u>	<u>Description/Comments</u>
Temperature Sensors/7	Omega Engineering	Type K, Model 3164-18
Pressure Transmitters/4	MKS Instruments	Model 223AH
Hydrocarbon Generator/1	Laboratory Data Control	Mark V
Self-Regulator Damper/1	Metal Industries	RETRO II
Duct Vacuum Control Damper/1	Damper Design	Type Q 6527
Control Dampers/6	Damper Design	Type 5736
I/P Converters/6	Babcock & Wilcox	Model AP-5
Damper Actuators/6	Sheffer Corporation	Model AA
Prefilter Station/2	CENITEC Process Systems	Filters, enclosures, eductors
Heated Sample Lines/3	Technical Heaters	Model LP 212-444-10
Hydrocarbon Analyzers/2	CPS/Ratfisch Instrumente	Model RS-555/8 and Model RS-55
Line Speed Indicator/1	Electro-Sensor Inc.	Model 906
CRT/1	Industrial Data Term.	Model C-3919N
Air Seal/2	Bildon Industries	Air barrier heat seal
Microcomputer/1	CENITEC Process Systems	Intel 8840 CPU, I/O, signal conditioner, cabinet
Printer/1	Epsom of America	MX-80
Calibration Gas/2	Air Products & Chemicals	1. Vol % Propane in Air
Incinerator/1	Hirt Combustion Eng.	0.1 Vol % Propane in Air
Control Room/1	East Penn Mechanical	Type HFH-5MX
		2.44 m wide x 3.05 m long x 2.44 m high (8 ft x 10 ft x 8 ft)
Insulation	John Mansville	427°C (800°F)
Ductwork/Installation	East Penn Mechanical	--
Oven Panels/34	East Penn Mechanical	--
Gas Meters/2	Romet	Rotary displacement
Incinerator Auxiliary Fan/1	Garden City Fan & Blower	330FF1000SW
Oven Exhaust Fan/1	Garden City Fan & Blower	21RF23200SW

COATER ROOM MODIFICATIONS

A new hood and exhaust blower were installed in the coater room to capture fugitive solvent emissions at the roll coater. The exhaust rate for the coater room was designed at 2.36 standard m³/s (5,000 stdft³/min). Continuous analyses of the coater room exhaust solvent concentration gave a reading of less than 2 percent of the LEL. The exhaust stack was sized for an exhaust velocity that would result in a 1000:1 dilution of solvent vapors. The EPA-approved model PTPLU (Version 80364) of Trinity Consultants, Inc., Dallas, Texas was used to predict the dilution of solvent vapors for sizing of the coater room exhaust stack.

Based on the predicted dispersion of solvent vapors and monitoring of the solvent vapors by the microprocessor system, Prior Coated Metals was not required to incinerate the exhaust from the coater room by the Department of Environmental Resources, State of Pennsylvania. Once the coater room hoods and exhaust system were installed the remaining odor problems were reduced or eliminated.

An additional benefit of venting the coater room air was reduced investment and operating costs for the incinerator. If the coater room air had required incineration, the air flow rate for an incinerator would have increased in order to handle the additional air flow from the coater room. Since the air from the coater room is at room temperature, a primary heat exchanger would have been required in order to minimize incinerator fuel demand. The investment cost savings for the incinerator was projected at \$140,000. The extra hourly natural gas demand of approximately 1171 KW (4 million Btu/h) was also saved. Therefore, due to these results the coater room emissions were not incorporated into the microprocessor control system.

CURING OVEN MODIFICATIONS

As shown in Table 3 and Figure 2, the major equipment and modifications for the curing oven to implement the microprocessor concept included dampers, damper actuators, electrical to pneumatic (I/P) converters; hydrocarbon analyzers (flame ionization types), filters, heated sample lines; temperature and pressure sensors, ductwork, insulation, air seals; a microcomputer controller, and natural gas meters. The existing oven burners and recirculation blowers (R1, R2, R3) were not changed. This section describes the function of the major equipment and the reasons for their use.

- ° Temperature Sensors - Temperature sensors were installed to provide continuous readings for the following process variables:

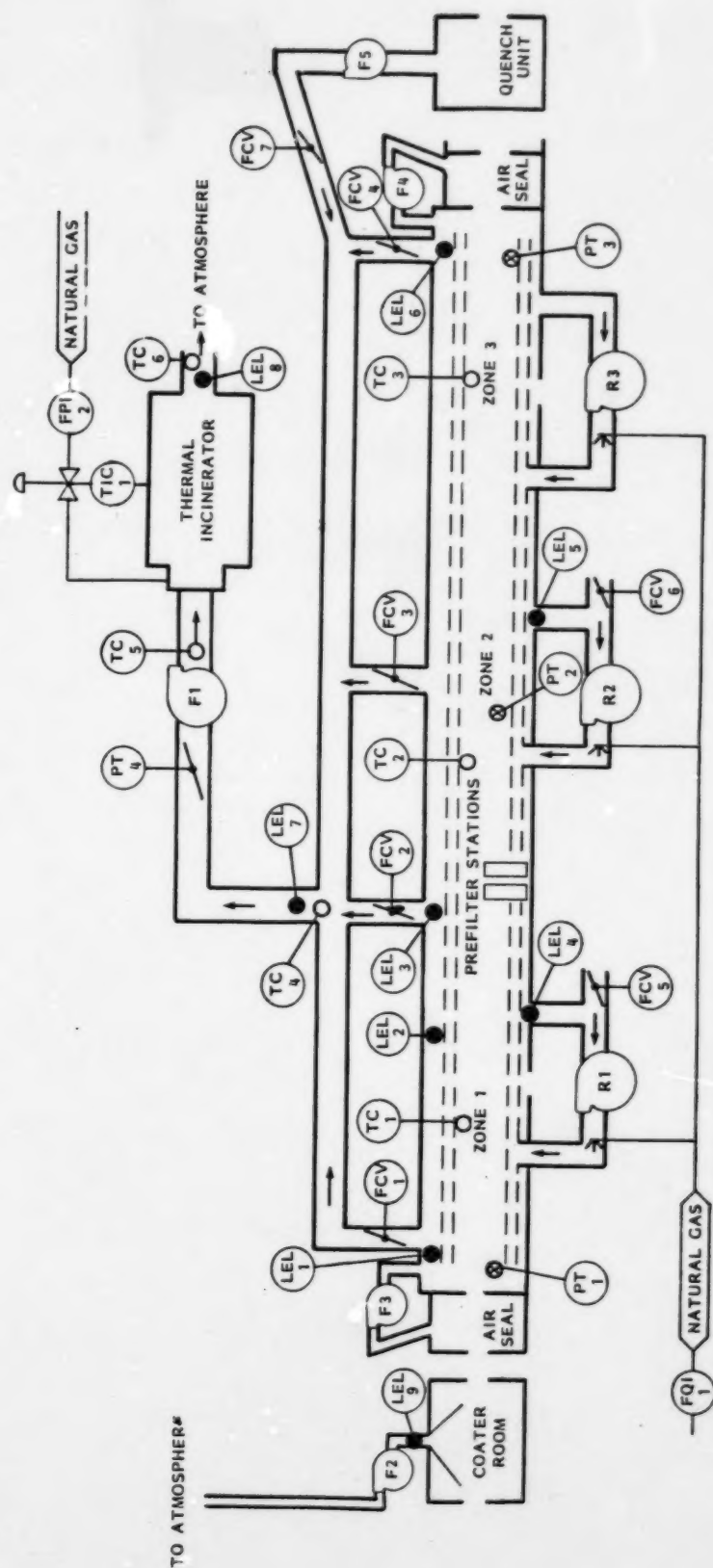


Figure 2. P&I Diagram microcomputer controlled coil coating oven (Refer Table 3&5)

- Zone Temperatures - One thermocouple was installed to provide continuous measurement of oven zone temperatures. These readings supplemented the existing temperature controller readings used to adjust the curing temperature in each zone of the curing oven. These readings were displayed on the CRT of the microcomputer controller. The thermocouple was positioned near the same location as the zone temperature controller sensors, beneath the top recirculation nozzles.
- Oven Exhaust Air Temperature - Two temperature sensors were located in the ductwork between the curing oven and incinerator. One sensor was located immediately after the four exhaust ducts were joined together. The second sensor was located at the inlet to the thermal incinerator, which was located on the roof of the facility approximately 9.14 m (30 ft) from the curing oven. These temperatures were displayed on the CRT and were incorporated to provide a means of monitoring heat losses in the ductwork and for calculating incinerator air heating demands.
- Incinerator Exhaust Temperature - A temperature sensor was installed in the duct at the discharge of the thermal incinerator. This reading was displayed on the CRT and supplemented the reading of the temperature controller provided with the thermal incinerator. This temperature sensor, when combined with the line speed indicator, was used to automatically reduce the incinerator exhaust temperature from the control set point of approximately 760 to 538°C (1400 to 1000°F). The set point was reduced to conserve fuel for the incinerator whenever production stopped, such as for paint formulation changes.
- Pressure Sensors - Four pressure sensors were used for monitoring and control. A pressure sensor was located in each of the three zones of the curing oven to maintain a slightly negative pressure inside the oven. The pressure was controlled by the microcomputer at a set point of approximately -2.49 Pa (-0.01 inches H₂O). If the pressure increased above this setting, then one or several of the exhaust dampers automatically opens to increase the ventilation air flow rate, thus reducing the pressure. Likewise, a higher negative pressure results in closure of the exhaust air damper(s) or opening of make-up air dampers. A fourth pressure sensor was installed with the duct vacuum control damper located before the incinerator blower. This reading was used to permit control of the pressure in the ductwork at -622.10 Pa (-2.5 inches H₂O) to prevent the pressure from exceeding the ductwork design vacuum of -747 Pa (-3.0 inches H₂O). All pressure readings were displayed on the CRT.

- Hydrocarbon Analyzers - Two Hydrocarbon Analyzers manufactured by Ratfisch Instrumente were installed in the control room along with the microcomputer controller. The analyzers included the Model RS-555/8, an eight-channel unit that simultaneously sampled from eight points, and a Model RS-55, which is a single-channel unit. Each model operates on the flame ionization principle of analyses for determining the percent of the LEL.

The points selected for monitoring and control of the solvent concentration inside the curing oven with the Model RS-555/8 are as follows:

- Four points in Zone 1 located at opening in the duct to the first exhaust damper, suction side of recirculation blower, above the recirculating ductwork and the second Zone 1 exhaust damper
- One point in Zone 2 located at suction side of recirculating blower;
- One point in Zone 3 located at inlet to Zone 3 exhaust damper;
- One point in the ductwork before the incinerator to measure the average concentration entering the incinerator;
- One point in the ductwork of the coater room to monitor average solvent concentration.

The Model RS-55 was dedicated to monitoring the exhaust solvent concentration of the incinerator.

The analyzers were equipped with flame-out indicators. The microcomputer would monitor the temperature of each flame ionization detector. This feature was incorporated so that a zero reading by any analyzer would be compared to the burner temperature, thereby assuring that a zero reading was indicative of lack of solvent instead of a malfunction, such as utility service shut-off.

The sampling points were selected to monitor the points of highest solvent concentration. Since Prior Coated Metals processes many coatings having different solvent compositions and boiling points, multiple points were selected to provide representative readings and control as solvent release points changed locations. Multiple sampling points were placed in Zone 1 of the curing oven where most of the solvent evaporation occurs. Only one point was

dedicated to Zones 2 and 3 because essentially all of the solvent is evaporated in Zone 1. Whichever point gives the highest reading became the controlling factor for the air flow rate from one or more of the four exhaust ducts. Each analyzer reading was displayed on the CRT. A solvent excursion resulting in a solvent concentration above 50 percent of the LEL would cause an alarm, full ventilation air flow rate, shut-off of natural gas to each of three burners, and lifting coater heads to prevent additional solvent from entering the oven. Resumption of coating cannot occur until all alarm conditions have been satisfied.

- Damper/Ductwork Modifications - The curing oven and incinerator, before retrofit, were on the same level in the facility. No dampers were installed and a single exhaust duct approximately 1.52 m (5 ft) long connected the curing oven and thermal incinerator.

Because of the need to install the incinerator on the roof and the requirement to exhaust from different locations in the oven for control of solvent concentrations, four exhaust ducts with dampers, damper actuators, and I/P converters were installed on top of the curing oven. The cross sectional area for the ducts are approximately 0.37 m² (4 ft²). Each exhaust duct was connected to a common duct manifold that ran the length of the curing oven.

Two exhaust ducts were installed in Zone 1. One duct was located approximately 2.44 m (8 ft) from the entry since Prior processes some coatings with low boiling solvents that evaporate very quickly. The second exhaust duct/damper assembly was located approximately 10.36 m (34 ft) from the entry to provide an exhaust point between Zone 1 and Zone 2 recirculation fans.

Single exhaust duct/damper assemblies were installed in Zone 2, approximately 17.07 m (56 ft) from the entry and in Zone 3 approximately 1.83 m (6 ft) from the back of the oven. The Zone 2 location was selected to exhaust VOC emissions from that location where the highest boiling solvent coatings would experience maximum solvent evaporation, such as those containing isophorone. The Zone 3 duct/damper assembly was positioned near the end of the oven to minimize the amount of ventilation air required to prevent puff-out of fumes through the air seal to the work area.

One additional duct with a self-regulating damper was also tied in to the manifold in order to exhaust air from

the quench unit as required for incineration. With a few coating formulations, the exhaust from the quench contains organics that are odoriferous. The self-regulating damper was set to maintain a flow rate of approximately 0.44 standard m³/s (940 stdft³/min). Typically this damper is normally closed unless odor control becomes necessary.

This ductwork was also installed joining the oven manifold duct to the incinerator.

- Duct Pressure Control Damper Assembly - A pressure controlled damper assembly was installed just before the incinerator in order to maintain the duct pressure above -745.62 Pa (-3 in H₂O). This unit included a pressure sensor, actuator, and damper. As the ventilation air flow rates are reduced in the curing oven, the suction pressure developed by the incinerator blower also reduces because it is a fixed speed blower. The blower at the controlled minimum air flow rate would produce a suction pressure of approximately 1991 Pa (8 in H₂O). This pressure would exceed the design pressure -747 Pa (-3 inches H₂O) of the ductwork. Therefore, this damper was controlled with the microcomputer to maintain the pressure at a set point of -622 Pa (-2.5 inches H₂O). The pressure and damper position are displayed on the CRT of the microcomputer.
- Make-Up Air Damper Assembly - Two makeup air damper assemblies were installed in the suction line for Zone 1 and Zone 2 recirculation fans. A new damper with damper actuator and I/P converter were included with each assembly. These dampers were automatically controlled to permit entry of fresh air into Zone 1 and Zone 2 as necessary for control of solvent concentrations and pressure in each zone. Air could be drawn from the ends of the oven but this would result in an uneven distribution of ventilation air inside the oven. Entry of the air at the recirculation fan results in a faster response and a more even distribution within each zone since the air is discharged through the nozzles of the distribution manifolds which run the length of each zone.
- Incinerator - A new thermal incinerator was installed to control odors and VOC emissions. The incinerator was designed for a residence time of 0.8 seconds at 2.28 standard m³/s (4840 stdft³/min) and 816°C (1500°F). The maximum operating temperature is 1093°C (2000°F). The burner is designed for a maximum firing rate of 1464 kW (5 million Btu/h) with a 12/1 turndown ratio. Maximum operation air flowrate was approximately 37.75 standard m³/s (8000 stdft³/min).

- Air Seals - Two air seals supplied by Bildon Industries were installed at the entry and discharge of the curing oven. The air seals were used to reduce the amount of smoke being carried out of the oven from the discharge end between the oven and the quench unit. Also, air seals would decrease the amount of air required to keep the curing oven under negative pressure. This prevents puff-out. The air seals reduced the total ventilation air flow volume required to prevent puff-out to approximately 1.65 standard m³/s (3500 stdft³/min). Therefore, under pressure control the amount of energy for air heating is equivalent to the minimum exhaust air flow rate, approximately 1.42 standard m³/s (3500 stdft³/min) and exhaust air temperature.

The air seals are 1.35 m long, 2.08 m wide, by 2.59 m high (53 inches long, 82 inches wide by 102 inches high). Each seal is equipped with a blower that recycles air from inside the oven through air seal nozzles that create a high velocity of air on the top and bottom of the coil, producing an air curtain that seals the ends of the curing oven.

- Sample Handling Equipment for Analyzers - The handling equipment includes sample probes, tubing connecting the sampler probes to prefilter station, and temperature controlled heated sample lines connecting the prefilter station to the analyzers.

As shown in Figure 2, two prefilter stations were employed. Each prefilter station was mounted inside the curing oven directly behind the control room. Each prefilter station contained three in-line stainless steel mesh prefilters. A single air eductor for each prefilter station provides the suction pressure for drawing the sample to the in-line prefilters. Instrument air was regulated to a pressure of 31.20 kPa (35 lb/in² g) for the eductor to create the suction pressure for each line connected to the prefilter station. The analyzer pump draws the sample at a rate of approximately 5 liters per minute from the in-line filter through the heated sample line to each analyzer.

For sampling of the hydrocarbons in the ductwork entering the incinerator (LEL 7) and at the discharge of the incinerator (LEL 8), an in-line stainless steel prefilter was used. These two sampling points were connected to the prefilter station by running stainless steel tubing inside the ductwork. No in-line filters were used in the prefilter station since the sample was filtered inside the ductwork. Each of these samples were also drawn to the

analyzer through a heated sample line by the analyzer pump. The sample from the coater room was connected to the analyzer with teflon tubing. Since the coater room exhaust temperature is approximately 27°C (80°F), no heated sample line was required. Each of the readings for the nine sampling points were displayed on the CRT. The solvent concentration was measured in terms of percent of the LEL.

● Miscellaneous Hardware

- Oven Insulation - The curing oven was insulated with two inches of asbestos insulation on the top of the curing oven. This insulation was replaced with 15.24 cm (6 in) of mineral wool insulation.
- Ductwork Insulation - For all high temperature ductwork, including four exhausts, manifold, and interconnecting ductwork between oven and incinerator, insulation of 10.16 cm (4 in) of calcium silicate was used.
- Line Speed Indicator - A line speed indicator, Model 906, was installed on a quench idler roll. The indicator provided a reading of line speed in feet per minute. This reading was displayed on the CRT. The total length of coated coil processed was calculated based on line speed and time of coating. The accumulated length of coil was also displayed on the CRT.
- New Curing Oven Panels - Due to the age of the curing oven, some of the roof panels had deteriorated to the point of fatigue and had holes in the material. Thirty-four roof panels were replaced to improve structural support of the oven and to prevent air leaks.
- Gas Meters - Two gas meters were installed to measure the curing oven fuel demand and incinerator fuel demand.
- Fans - One new fan was installed. The new fan was used for start-up of the incinerator. The second fan used for operation after start-up of the incinerator was the one Prior had used with the old incinerator.
- Hydrogen Generator - Pure hydrogen is required as a fuel source for the hydrocarbon analyzers. The hydrogen generator is an electrolytic unit that produces hydrogen from deionized water. A pressure sensor was installed in the hydrogen line to the analyzers in order to detect low pressure that could

affect the operation of the analyzers. In addition to hydrogen pressure, a low level indicator was installed in the deionized water reservoir to forewarn the operators to fill the container before it ran dry. The hydrogen pressure was displayed on the CRT.

- Calibration Gases - Two non-flammable calibration gas cylinders were installed in order to calibrate the hydrocarbon analyzers. The gases used contained a mixture of propane and air, one resulting in equivalent reading of 45 percent of the LEL for Model RS-555/8 analyzer. Since the exhaust concentration of the incinerator would be less than 1 percent of the LEL, the calibration gas used for the Model RS-55 analyzer gave a reading of 1 percent of the LEL upon calibration.
- Utility Requirements - In addition to hydrogen and calibration gases, the system required clean, dry, oil-free air for the analyzers and damper controllers and 115 Vac power supply for analyzers and micro-computer.

MICROCOMPUTER FUNCTIONS

The microcomputer was designed and assembled by CENTEC Process Systems. The major components of the microcomputer included power supply, Intel 88/40 CPU board, timer board, CRT driver board, serial/parallel P/O board, analog output boards, input/output signal conditioners, OPTO 22 digital P/O signal conditioning, and 48 cm (19-inch) color CRT. A printer was also supplied and integrated into the system. Control software was completed and contained in EPROM. Control constant changes and set point changes for pressure and solvent concentration readings were made by use of a numeric keypad mounted on the computer cabinet.

The original total ventilation air flow rate of the curing oven was approximately 7.27 standard m^3/s (15,400 stdft³/min). Since the incinerator was designed to handle approximately 3.78 standard m^3/s (8,000 stdft³/min) of air, that air flow rate became the new maximum ventilation air flow rate for Prior's curing oven. The final objective was to reach a minimum ventilation air flow rate of approximately 1.65 standard m^3/s (3500 stdft³/min) which meant that air seals and accurate pressure control would be required to maintain a minimum in draft for both ends of the curing oven through the air seals.

Since Prior processes many different coatings with multiple solvent mixtures, the locations in the oven of highest solvent release had to be ventilated in order to meet the National Fire Protection Association 86-A Codes for continuous curing ovens. Thus, the fail-safe regulations of the NFPA were incorporated into the design of the control system.

A coil coating oven operates at high line speeds resulting in the quick release of solvent into the oven. The coil was typically completely cured within 33 seconds at a line speed of 0.97 standard m/s (180 ft/min), and with an oven length of approximately 30.48 m (100 ft). Since the majority of the solvent is evaporated from the coated coil, prior to final cure, the control response to changes must be less than 33 seconds. The control of ventilation air flow rates at different locations in the oven and use of multiple hydrocarbon analyzer sensors and pressure sensors were the important design criteria of the control system along with the safety regulations.

The inputs and functions of each sensor for the microcomputer control system are presented in Table 4 and Table 5, respectively. The major control parameters were pressure and solvent concentration. Each sampling point inside the curing oven was dedicated to fail-safe actions. The control functions of increasing or decreasing the ventilation air flow rate were implemented by changing damper positions. The controlled damper(s) were closest to the location of the maximum solvent concentration reading.

For pressure control, the increase or decrease in ventilation or make-up air flow rate was maintained by the dampers located in each zone of the curing oven.

A typical sequence for the automatic control of Prior's oven/incinerator follows:

- Analyzers and microcomputer are turned on
- Analyzers are calibrated
- Ventilation and make-up air dampers are positioned manually with the microcomputer
- The curing oven and incinerator are brought up to temperature
- During the preheat (start-up) cycle of the curing oven, the microcomputer controls the ventilation air flow rate at a rate based on pressure set points
- The line is started up with non-coated strip entering the oven; this puts the microcomputer in a standby state with full ventilation air flow rates being maintained

TABLE 4. INPUTS/OUTPUTS FOR MICROCOMPUTER CONTROLLER
(Refer Figure 2)

Inputs to Microcomputer Controller

- Solvent Concentrations - LEL 1,2,3,4,5,6,7,8,9
- Pressure Readings - PT 1,2,3,4
- Temperature Readings - TC 1,2,3,4,5,6
- Coater Head Positions - Up/down
- Conveyor Line Speed Indicator - fpm
- Flame-Out Indicators for Analyzer - LEL 1,2,3,4,5,6,7,8,9
- H₂ Fuel Pressure for Analyzers
- Instrument Air Pressure for Analyzers
- Alarm Disengage
- H₂ Generator Water Level Indication
- Low Air Flow to Eductors in Prefilter Stations

Outputs From Microcomputer Controller

- Change damper positions - FCV 1,2,3,4,5,6 and PT 4 for Pressure & LEL Control
- Idle Temperature Setting for Incinerator - TIC 1
- Span Gas Injection for Prefilter Stations, 6 total
- Lift Coater Head
- Shut-Off Fuel to Curing Oven Burners for Greater Than 50% of the LEL
- Shut-Off Fuel to Incinerator Burner
- Alarm Light
- Alarm Horn
- Alarm Report Generation

TABLE 5. SUMMARY OF FUNCTIONS FOR SENSORS AND HARDWARE
FOR MICROCOMPUTER CONTROLLER
(Reference 2)

P&I Designation	CKT Display	Control	Monitor Only	Equipment Description	Functions
LEL 1	Yes	Yes	No	Model RS-555/8 Analyzer	Air flow rate and fail safe control with FCV-1
LEL 2	Yes	Yes	No	Model RS-555/8 Analyzer	Air flow rate and fail safe control with FCV-2, 5
LEL 3	Yes	Yes	No	Model RS-555/8 Analyzer	Air flow rate and fail safe control with FCV-2, 5
LEL 4	Yes	Yes	No	Model RS-555/8 Analyzer	Air flow rate and fail safe control with FCV 2, 5
LEL 5	Yes	Yes	No	Model RS-555/8 Analyzer	Air flow rate and fail safe control with FCV 3, 6
LEL 6	Yes	Yes	Yes	Model RS-555/8 Analyzer	Air flow rate and fail safe control with FCV-4
LEL 7	Yes	No	Yes	Model RS-555/8 Analyzer	Monitor average solvent concentration
LEL 8	Yes	No	Yes	Model RS-555/8 Analyzer	Monitor exhaust concentration from incinerator to calculate efficiency
LEL 9	Yes	No	Yes	Model RS-555/8 Analyzer	Monitor exhaust from coater room
PT 1	Yes	Yes	No	Pressure sensor/controller	Maintain in draft from entry of oven with FCV-2, 5
PT 2	Yes	Yes	No	Pressure sensor/controller	Maintain negative pressure in Zone 2 with FCV-3, 6
PT 3	Yes	Yes	No	Pressure sensor/controller	Maintain in draft from back of oven with FCV-4
PT 4	Yes	Yes	No	Pressure sensor/controller	Control damper setting to maintain back pressure on ductwork
TC 1	Yes	No	Yes	Thermocouple	Monitor Zone 1 temperature
TC 2	Yes	No	Yes	Thermocouple	Monitor Zone 2 temperature
TC 3	Yes	No	Yes	Thermocouple	Monitor Zone 3 temperature
TC 4	Yes	No	Yes	Thermocouple	Monitor exhaust temperature from curing oven
TC 5	Yes	No	Yes	Thermocouple	Monitor inlet temperature of air entering incinerator
TC 6	Yes	No	Yes	Thermocouple	Monitor exhaust temperature, control idle temperature of incinerator
TIC 1	No	Yes	No	Temperature controller	Controls fuel demand and exhaust temperature of incinerator
FCV 1	Yes	Yes	No	Damper/actuator/I/P convertor	Controls pressure and LEL levels in Zone 1
FCV 2	Yes	Yes	No	Damper/actuator/I/P convertor	Controls pressure and LEL levels in Zone 1
FCV 3	Yes	Yes	No	Damper/actuator/I/P convertor	Controls pressure and LEL levels in Zone 2
FCV 4	Yes	Yes	No	Damper/actuator/I/P convertor	Controls pressure in Zone 3 if required
FCV 5	Yes	Yes	No	Damper/actuator/I/P convertor	Controls make-up air flow rate for Zone 1 for pressure and LEL control
FCV 6	Yes	Yes	No	Damper/actuator/I/P convertor	Controls make-up air flow rate for Zone 2 for pressure and LEL control
FUI 1	No	No	Yes	Gas meter	For on-line measurement of natural gas demand for curing oven
FUI 2	No	No	Yes	Gas meter	For on-line measurement of natural gas demand for incinerator
FCV 7	No	No	No	Self-regulating damper	Control of smoke and odors from quench unit, manually set

- With the coater head position sensor, the microcomputer monitors the status of coating. Once the coater heads drop, indicating that coating is being applied to the strip, the microcomputer begins control by sensing solvent concentration inside the oven.
- Ventilation and make-up air flow rates are controlled by changing the appropriate positions of the dampers to maintain the curing oven at the solvent concentration set-point of 30 to 35 percent of the LEL or to the minimum ventilation air flow rates based on pressure set-points.
- When the line stops for coating formulation changes, the microcomputer maintains the minimum ventilation air flow rate and reduces incinerator exhaust temperature to 538°C (1000°F).
- When the line is started up again, the cycle repeats for control.

The safety controls are in operation at all times. If the solvent concentration at any point inside the oven exceeds 45 percent of the LEL, the caution light is turned on. If the concentration exceeds 50 percent of the LEL, the microcomputer shuts off fuel to the three burners of the curing oven and to the burner of the incinerator, lifts the coater heads to prevent solvent from entering the oven, and completely opens FCV-2 allowing full ventilation air flow. If the microcomputer senses a flame-out of more than one of the analyzers sampling inside the curing oven, the microcomputer operates at full ventilation air flow rates until the problem is corrected.

DISPLAY AND REPORTS

An example of the operator's display on the CRT for the microcomputer control system at Prior Coated Metals is shown in Figure 3. The numerical and status information displayed on the CRT screen is automatically updated once a second.

(Automatic)

COATER HEAD	IN	DAMPER POSITIONS						
DES. EFF.	99.8 %	ZONE	- 1E	1I	1EA	2E	2I	3E
COIL LENGTH	46788 FT	%OPEN	0	15	45	0	0	0
LINE SPEED	178 fpm							
SENSOR LOCATION		%LEL	degF		PRESSURE			
ZONE 1 - EXHAUST		28.8						
RECIRC		25.3	497		-0.010 in H2O			
OVEN		35.8						
AUX EXHAUST		15.8						
ZONE 2		3.0	563		-0.02 in H2O			
ZONE 3 EXHAUST		0.8	512		-0.01 in H2O			
OVEN EXHAUST			479					
INCINERATOR - INLET		18.9	427					
EXHAUST		.1	1400					
COATER EXHAUST		0.2						
MAKE-UP AIR			51					
HYDROGEN					36			

Figure 3. Microcomputer CRT Screen Display
(Typical Conditions with High Solvent Coatings)

SECTION 4

ENVIRONMENTAL AND ENERGY BENEFITS AND OPERATING RESULTS

STATUS OF PROJECT

Prior Coated Metals initially started the project during March 1982 with the initial installation of the analyzers and sample handling system. The final ductwork revisions and installation of the microcomputer were completed during October 1982. Subsequent controlled testing of the oven and incinerator led to the installation of the first air seal (curtain) at the back of the curing oven during December 1982, thereby reducing the minimum ventilation air flow rate from approximately 2.60 standard m^3/s (5500 stdft³/min) with one seal. The installation of the second air seal was completed during May 1983, at which time a test showed that the minimum ventilation air flow rate of 1.65 standard m^3/s (3500 stdft³/min) could be reached. Because of the timing of the report, it was not possible to collect data with both air seals in place. Therefore the operational data herein reflect only one operational air seal.

This section presents the results of the operation with Prior's total investment, operating costs, and emission control achievements. Also, the projection of annual fuel costs are presented and compared with the operating costs prior to retrofit.

INVESTMENT COSTS

The hardware and installation costs for the microcomputer control system, incinerator, and oven panel replacements are shown in Table 6. The total installed investment was \$478,100 which included both system costs, plant modifications, and updates.

OPERATING RESULTS

The operating conditions after retrofit for three different coating formulations are shown in Table 7 along with the fuel demands for the curing oven and thermal incinerator. These data were collected with only one air seal in place (end of oven) so the minimum air flow rate was 2.60 standard m^3/s (5500 stdft³/min). The installation and operation of the second air seal should result in an additional flow reduction and cost savings.

TABLE 6. INVESTMENT COSTS

CPS Microcomputer Control System Including Analyzers, Sample Handling Equipment, Sensors, Dampers, Damper Actuators, and I/P Converters	\$220,900
HIRT Thermal Incinerator and Auxiliary Equipment	70,900
Thermal Incinerator Installation and Start-up Services	56,400
Curing Oven Panel Replacement	20,100
Installation and Engineering Service Costs for Ductwork, Air Seal Installation Costs, Insulation, Electrical Wiring and Control System	<u>109,700</u>
Total Installed Investment	\$478,100

Table 7. OPERATING CONDITIONS AND FUEL DEMAND
FOR MICROCOMPUTER CONTROL SYSTEM
AND INCINERATOR

Run Number	1	2	3
<u>Curing Oven Conditions</u>			
Line speed, m/s (ft/min)	91 (180)	91 (180)	91 (180)
Solvent rate, m ³ /s (gal/min)	0.00002 (0.3)	0.00001 (0.8)	0.0001 (1.0)
Temperature, °C (°F)			
- Zone 1 (TC1)	353 (667)	260 (500)	283 (541)
- Zone 2 (TC2)	400 (752)	282 (540)	251 (483)
- Zone 3 (TC3)	349 (660)	282 (540)	239 (462)
- Oven Exhaust (TC4)	336 (637)	238 (460)	263 (505)
- Incinerator Inlet (TC5)	294 (561)	224 (435)	217 (422)
- Incinerator Exhaust (TC6)	732 (1350)	760 (1400)	760 (1400)
Pressures, Pa (inches H ₂ O)			
- Zone 1 (PT 1)	1.99 (0.008)	1.99 (0.008)	8.46 (0.034)
- Zone 2 (PT 2)	2.48 (0.010)	2.49 (0.010)	2.49 (0.010)
- Zone 3 (PT 4)	2.49 (0.010)	2.49 (0.010)	0 (0)
Avg. Ventilation Air Flow			
Rate, std m ³ /s (stdft ³ /min)	2.60 (5500)	3.26 (6900)	3.54 (7500)
<u>Solvent Concentrations % of the LEL</u>			
LEL 1	16	23	27
LEL 2	11	35	28
LEL 3	7	18	13
LEL 4	9	11	28
LEL 5	1	2	1
LEL 6	1	<1	<1
LEL 7	6	17	14
LEL 8	No	No	No
LEL 9	<1	1	<1
Incinerator Destruction			
Efficiency %	99.9	99.9	99.9
Fuel Demands, MW (million Btu/h)			
- Total for Curing ¹	1.49 (5.1)	1.49 (5.1)	1.58 (5.4)
- Total for Incineration ¹	1.70 (5.8)	1.05 (3.6)	0.88 (3.0)
- Total for Incineration & Curing	3.19 (10.9)	2.55 (8.7)	2.46 (8.4)
- Radiation Losses ²	0.59 (2.0)	0.59 (2.0)	0.59 (2.0)
- Metal Heating ²	0.32 (1.1)	0.26 (0.9)	0.21 (0.7)
- Total for Air Heating	2.28 (7.8)	1.70 (5.8)	1.67 (5.7)

¹Meter readings as reported by Prior Coated Metals

²Calculated values by Prior Coated Metals

NOTE: Refer Figure 2

During Run No. 1, the oven was controlled at 2.60 standard m^3/s (5500 stdft³/min), total ventilation air flow rate. At this ventilation air flow rate and solvent evaporation rate, the maximum solvent concentration was reached at 16 percent of the LEL in the beginning of Zone 1. The oven was controlled by damper (FCV 2) and the oven was operated under pressure control. The total natural gas demand was 3192 kW (10.9 million Btu/h for the incinerator and curing oven, was approximately 228 kW (7.8 million Btu/h) for total air heating.

During Runs 2 and 3, the curing oven was operated under LEL control at set points of 35 percent of the LEL and 30 percent of the LEL, respectively. The resultant total ventilation air flow rates were 3.26 standard m^3/s (6900 stdft³/min) for Run 2 and 3.54 standard m^3/s (7500 stdft³/min) for Run 3. The damper FCV 2 was the main exhaust flow damper for Run No. 2 while damper FCV 1 controlled ventilation air flow rate for Run No. 3. The use of different dampers for control was dependent on the areas of highest solvent release with Run No. 3 resulting in a release point within the first 6.10 m (20 ft) from the entry to the curing oven.

As shown in Table 7, the energy demand at Prior Coated Metals was dependent upon the curing temperature solvent evaporation rate and total ventilation air flow rate to maintain pressure or LEL control. With the control system, the energy demand for curing was directly proportional to the total ventilation air flow rate, curing temperature, and solvent evaporation rate. Therefore, the yearly average energy demand becomes dependent upon the coating formulation requirements. This determines the final controlled ventilation air flow rates based on the pressure and/or solvent concentration set points.

During start-up and coating formulation changes, the controller sets the ventilation air flow rate under pressure control at approximately 1.89 standard m^3/s (4000 stdft³/min) and incinerator exhaust temperature of 538°C (1000°F). This means that the total air heating demand for the curing oven and incinerator was approximately 1377 kW (4.7 million Btu/h) for a curing oven exhaust temperature of 343°C (650°F). Without the control system in place, the curing oven ventilation air flow rate was approximately 6.37 standard m^3/s (13,500 stdft³/min) at the same temperature which had resulted in a fuel demand of approximately 4627 kW (15.8 million Btu/h) for air heating for the curing oven and incinerator before retrofit.

Since the total annual fuel demand is dependent upon coating requirements, the annual fuel cost for the control system is projected based on an estimate of their production requirements. The total average hourly fuel demand is estimated

to be 1962 kW (6.7 million Btu/h), approximately 1113 kW (3.8 million Btu/h) for air heating. The conditions from which the energy demand for curing and incineration are indicated in Table 8.

Using the projected annual energy demand for curing (Table 8) the operating costs of Prior's system before and after the retrofit are presented in Table 9. The annual fuel savings are estimated to be \$311,000 based on a fuel cost of \$4.75 per kW (million Btu/h). The after-tax payback and discounted cash flow rate of return on total installed investment are estimated to be 1.8 years and 38 percent, respectively. Prior's (1983) fuel cost is \$6 per KW (million Btu/h) which resulted in an annual fuel savings during 1983/1984 to approximately \$393,000.

POLLUTION CONTROL

The destruction efficiency objective was easily reached by installing a thermal incinerator. Therefore, Prior's total VOC emissions from the coater room and oven were below those required. Figure 4 shows the destruction efficiency of the incinerator over a range of controlled exhaust temperatures. The destruction efficiency was determined continuously with the microcomputer from solvent concentration readings, LEL 7 and LEL 8, Figure 2. Since a destruction efficiency of greater than 98 percent was achieved at an incinerator exhaust temperature of 704°C (1300°F), the incinerator is being operated at 704°C (1300°F) instead of 760°C (1400°F).

Smoke and fugitive emissions control were also achieved. The installation of the air seal in the back of the curing oven prevented smoke from entering the work area by forcing it back into the oven where it was exhausted and incinerated. Fugitive emissions from inside coater room were eliminated by installing a hood over the coater applicator and increasing the air flow rate from approximately 1.04 to 2.36 standard m³/s (2200 to 5000 stdft³/min).

TABLE 8. AVERAGE AND MINIMUM
ENERGY DEMAND AND CONDITIONS

Curing Oven Conditions

Line Speed, m/s (ft/min)	0.91 (180)
Solvent Rate, m ³ /s (gal/min)	0.00003 (0.4)
Oven Exhaust Temp, °C (°F)	343 (650)
Incinerator Inlet Temp, °C (°F)	316 (600)
Incinerator Exhaust Temp, °C (°F)	704 (1300)
Avg. Exhaust Conc, % of the LEL	20
Ventilation Air Flow rate, std m ³ s (stdft ³ /min)	2.12 (4500)
Controlled Set Point, % of the LEL	35
Pressure Control Set Point, Pa (inches H ₂)	1.99 (0.008)

Fuel Demands, MW (million Btu/h)

Total for Curing Oven	1.37 (4.6)
Total for Incineration	0.62 (2.1)
Total for Incineration and Curing	1.99 (6.7)
Radiation Losses	0.59 (2.0)
Metal Heating	0.26 (0.9)

Total Demand for Air Heating (ambient to 760°C) 1.14 (3.8)

TABLE 9. EVALUATION OF CONDITIONS AND ENERGY DEMAND
AND COSTS FOR CURING OVEN AND INCINERATION

Oven/Incinerator Before Retrofit

● Air Flows Requiring Incineration, std m ³ /s (stdft ³ /min)	
Curing Ventilation Air Flow Rates	5.76 to 7.27 (12,200 to 15,400)
Quench Air Flow Rate	0.44 (940)
Coater Room Air Flow Rate	0.33 (690)
Total Air Flow Rate, Range	6.53 to 8.04 (13,830 to 17,030)
● Range of Solvent Evaporation Rates, m ³ /s (gal/min)	0.00001 to 0.0001 (0.1 to 1.0)
● Range of Oven Curing Temperatures, °C (°F)	232 to 427 (450 to 800)
● Incinerator Exhaust Temperature, °C (°F)	538 to 649 (1,000 to 1,200)
● Total Average Hourly Fuel Demand, MW (million Btu/h)	5.15 (17.6)
● Annual Fuel Cost ¹	\$502,000

Oven/Incinerator After Retrofit

● Air Flows Requiring Incineration, std m ³ /s (stdft ³ /min)	
Curing Ventilation Air Flow Rates	1.65 to 3.3 (3,500 to 7,000)
Total Air Flow Rate, Range	1.65 to 3.3 (3,500 to 7,000)
● Range of Solvent Evaporation Rates, m ³ /s (gal/min)	0.00001 to 0.0001 (0.1 to 1.0)
● Range of Oven Curing Temperatures, °C (°F)	232 to 427 (450 to 800)
● Incinerator Exhaust Temperature, °C (°F)	704 (1300)
● Total Average Annual Fuel Demand, MW (million Btu/h)	1.96 (6.7)
● Annual Fuel Cost ¹	\$191,000
● Projected Annual Energy Savings	\$311,000

Economics²

Total Installed Investment (TII)	\$478,100
After Tax Payback on TII	1.8 yrs
Discounted Cash Flow Rate of Return	38 %

¹Annual fuel cost-6000 hours/yr operation, \$4.75 per million Btu for natural gas

²Based on fuel cost increase of 15%/yr

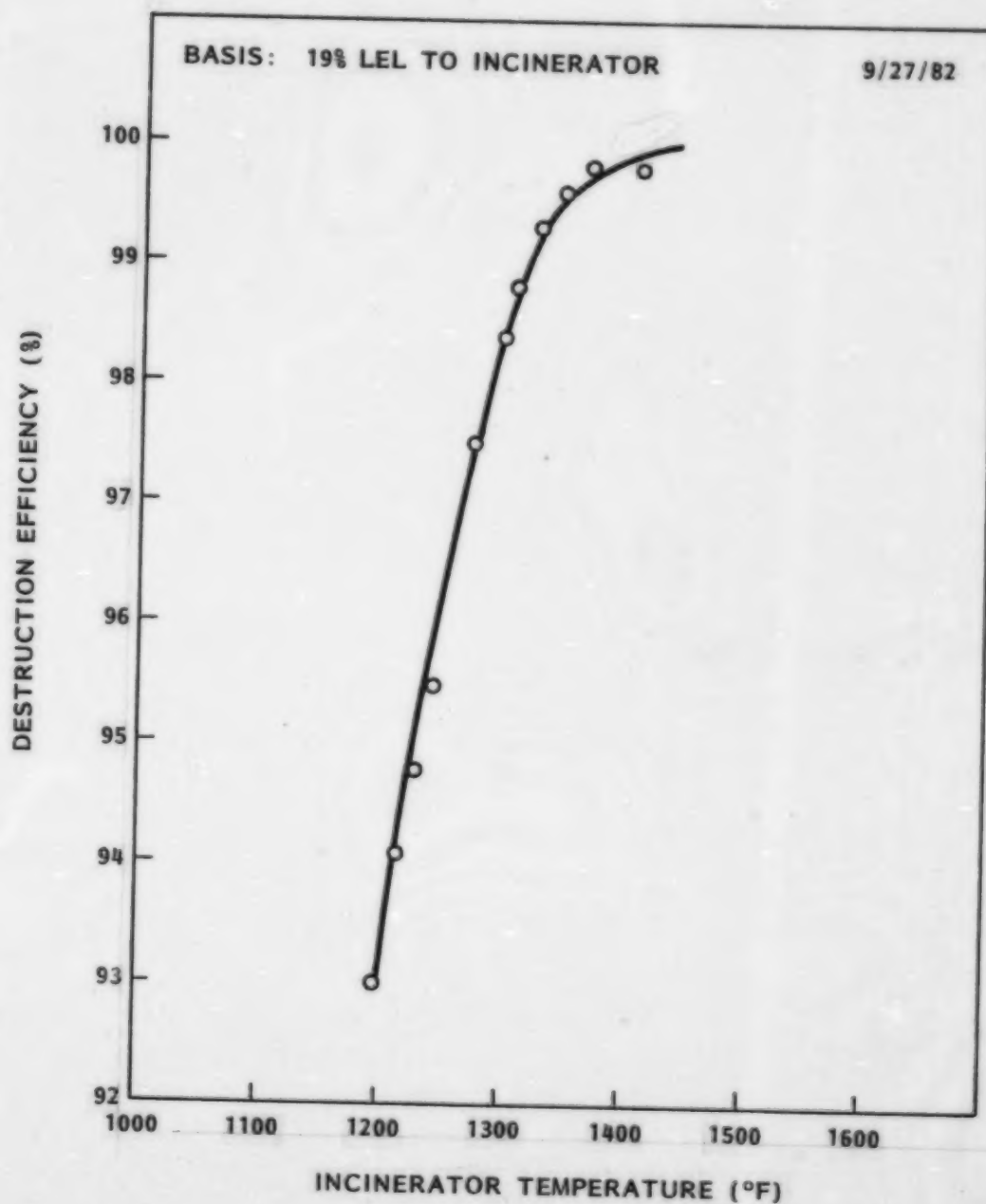


Figure 4. Destruction efficiency vs. temperature
Prior Coated Metals - Allentown